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WORK PERFORMANCE WITH MUSIC:
INSTRUMENTATION AND FREQUENCY RESPONSE

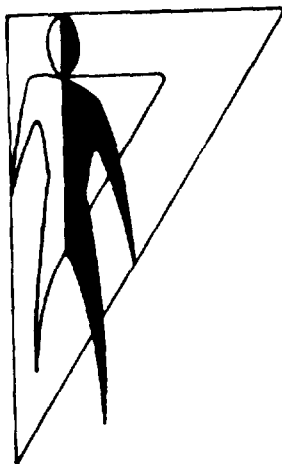
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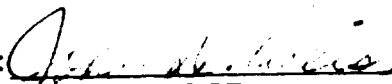
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WORK PERFORMANCE WITH MUSIC:
INSTRUMENTATION AND FREQUENCY RESPONSE

William Wokoun

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APPROVED: 
JOHN D. WEISZ
Technical Director
Human Engineering Laboratories

U. S. ARMY HUMAN ENGINEERING LABORATORIES
Aberdeen Proving Ground, Maryland

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ABSTRACT

(6)
This experiment tested whether music's instrumentation affects response times on a vigilance task. Instrumentation was varied by restricting the frequency range, thus eliminating many of the overtones that determine timbre. Forty-one subjects worked at the task for one hour while listening to a program of 23 selections, alternately Wide-Range and Filtered. The subjects showed significantly better alertness during the Wide-Range condition throughout the hour. The Filtered condition gave slower responses, greater variability, and inferior individual consistency. Hence the music's instrumentation had several significant effects on alertness. In addition, the more stimulating musical program here appeared responsible for faster responses and lower variability than in the preceding experiment.

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WORK PERFORMANCE WITH MUSIC:

INSTRUMENTATION AND FREQUENCY RESPONSE

INTRODUCTION

The discovery that human observers, searching for targets on radar scopes, could not perform their jobs effectively for much more than half an hour was a momentous one, with far-reaching implications. It focussed attention on a troublesome and ironic fact about human functioning on monotonous tasks: doing nothing is a hard job, and one which people do not perform with any great distinction.

These monotonous assignments are usually called vigilance tasks -- that is, work situations where people try to respond quickly and accurately, even though stimuli occur infrequently. Within the military, many of these vigilance tasks are critically important: not only detecting faint targets on the radar scope or monitoring a complex, automated missile system, but even such prosaic assignments as watching for aircraft. Vigilance is also an important element in many civilian jobs, such as a long-distance truck driver, an assembly-line inspector, or a worker who operates automated machinery. These men need not respond constantly, and often not even rapidly; yet they must always be ready to.

Despite the importance of these functions, it often proves impractical or impossible to have machines take them over completely. Since men must work at vigilance tasks, a large body of research has pursued possibilities which promised to help human operators maintain their alertness. This experiment, and the two preceding it, investigated whether manipulating environmental stimuli could improve vigilance.

The first experiment (3) demonstrated that a program of music can *not* only maintain alertness, but can actually improve performance at a monotonous task. The second experiment (4) linked the program's general musical characteristics to changes in behavior. The results showed that a single group of musical selections will have quite different effects when the selections are given in different orders. More specifically, these experiments support the theoretical position advanced by O'Neill (2), which maintains that the "stimulation value" of a given musical arrangement depends on such variables as tempo, rhythm, instrumentation, and orchestral size.

Logically, the next step in experimentation should be manipulating each of the variables singly, while holding all others constant, to observe how they affect alertness at the vigilance task. While this approach is easy to state, it proves stubbornly difficult to implement. The experimenter cannot readily obtain two recordings of a selection using, for example, different tempos -- yet identical in all other ways. Working with available recordings, he has no direct way to manipulate rhythm, instrumentation, or orchestral size. Yet the average psychologist is not prepared to commission his own arrangements and conduct recording sessions to prepare musical programs for his specialized purposes.

On the other hand, there are many ways to process music electronically. If one of O'Neill's variables could be translated into physical terms, it might then become amenable to electronic manipulation in the psychological laboratory.

Instrumentation is such a variable. O'Neill has stated that some instruments sound more stimulating than others do. For example, he considers strings least stimulating, woodwinds intermediate, and brass instruments most stimulating. For the moment, we will refrain from speculating about why the waveform of a trumpet might be more stimulating than a violin's.

Why, though, does a trumpet sound different from a violin? According to Fourier's theory, any complex waveform can be analyzed into component sine waves. Since sine waves have a precise mathematical definition, one sine wave is much like any other; they differ only in frequency and amplitude. Thus when two instruments play the same musical note, their fundamental frequencies are nearly identical. In fact, one Bell Laboratories demonstration (1) shows that a soprano, a piano, and a factory whistle sound alike -- if the harmonics are filtered out so we hear only the fundamental pitch.

For it is the harmonics -- multiples of the fundamental frequency -- that give musical instruments their characteristic timbres. Instruments sound different because they generate varying numbers and intensities of harmonics. If the overtones could be removed entirely, differences in instrumentation would virtually vanish; one instrument would sound about like all the others.

Even if it were technically feasible to remove all overtones from a musical recording, it would not be desirable to make the sound so drab and colorless. Nevertheless, the key to managing the instrumentation variable in experimentation lies in the fact that a harmonic always has a higher frequency than its fundamental. It is simple to remove high frequencies with an electronic filter, although we can never completely separate fundamentals and harmonics; occasional high-pitched fundamentals may be lost, while very low frequencies will still retain most of their harmonics. Still, removing higher frequencies will selectively discriminate against harmonics, while leaving the fundamentals relatively unaffected.

Restricting an audio system's high-frequency response will reduce the music's harmonic content, thereby reducing the differences in instrumentation. O'Neill has asserted that variations in instrumentation make music more stimulating. If so, music reproduced with a wide frequency range should be more stimulating. Consequently, it should maintain the subjects' alertness better and yield faster response times.

METHOD

Subjects

The subjects were 41 male students from the author's classes at the Human Engineering Laboratories.

Experimental Rooms

Each subject was tested while seated alone in one of four Industrial Acoustics Co. model 402-A audiometric booths. These booths effectively isolated the subjects from most of the extraneous noises they would otherwise have heard. Inside, the booths were approximately 6 feet square by 6 1/2 feet high. A vigilance stimulus box was on the table in front of the subject. To his left, on the floor, there was a seven-inch loudspeaker in a closed baffle.

Music

In developing the musical program for the present experiment, it was possible to take advantage of several findings from the previous studies. In the second study (4), the experimenter chose the 23 selections more or less randomly, as a block from an existing program. While this procedure can be defended as random sampling, it unfortunately led to a heavy preponderance of slow and medium selections. To avoid repeating this bias, the author asked O'Neill to select another set of 23 selections so they would encompass a broader range of stimulation values. Table 1 compares the previous program and O'Neill's new program by classifying the selections into four broad categories.

TABLE 1

O'Neill's Classification of Selections
in Present and Previous Programs

Descriptive Category	Number of Selections	
	Present Program	Previous Program
Fast	5	1
Bright	9	1
Medium	8	11
Slow	1	10
Total	23	23

While both programs span the range from "slow" to "fast" selections, the new program spreads the selections over the categories more evenly. As a whole, the new program is much more stimulating than the previous one; only two selections in the previous program were "bright" or "fast," but more than half of the new program falls in these classes.

The findings of the previous study showed clearly that subjects perform better with an ascending order of selections -- one which becomes gradually more and more stimulating. Therefore O'Neill arranged the 23 selections in the new program into an ascending order.

Muzak played each selection from a disc and copied it onto a 7 1/2 inch per second full-track tape recording, which was used as a master in preparing processed tapes for the experiment.

The details of the new program developed for this experiment are shown in Table 2.

TABLE 2

Program of Musical Selections and Stimuli

Music Program		Stimuli	
Start Time	Selection	Time	Stimulus Tube
:00	This is My Song	1:40	2
2:21	*Sunny	5:09	1
5:39	Born Free		
8:40	*More and More	9:25	3
11:40	So Nice	13:16	3
14:34	*Ode to Billy Joe		
17:23	Incense and Peppermints	18:38	4
20:12	*Music to Watch Girls By	21:02	1
22:31	Hallelujah, Baby		
25:19	*Please Wait	26:25	1
27:58	Magnificent Seven	28:58	2
30:08	*The Man Who Took the Valise		
33:02	Don't Sleep in the Subway	33:52	2
35:51	*Up, Up, and Away	37:55	1
38:06	Samba Orfeu		
41:22	*Only Love Me	42:29	4
43:40	Puppet on a String	44:36	2
46:01	*Stout Hearted Men		
48:05	Brasilia	49:25	4
50:23	*Nancy Knows	52:13	3
52:37	Brasileando		
54:41	*If You'll Just Come Back to Me	55:31	3
57:12	I've Got Rhythm	59:12	4
59:32	(End of program)		

* Starred selections were filtered to restrict frequency range
(see text).

Frequency Range

The independent variable was the music's frequency range. Alternate selections -- those which would have even numbers, as starred in Table 2 -- were filtered electronically to remove a substantial portion of the high-frequency range.

Odd-numbered (unstarred) selections were not subjected to any deliberate frequency restriction. However, the tape speed of the cartridge system itself, as well as degradation during copying the master tape onto the cartridge, necessarily produced some attenuation at high frequencies. This effect was assessed under the same conditions the music would be subject to, by recording constant-intensity sine waves on a cartridge, playing them back, and measuring the output level for each frequency. These calibrations showed that the system's overall frequency response was flat within ± 2 decibels (dB) as high as 6000 Hertz (Hz), then began to drop. The attenuation was 7 dB at 8000 Hz, and 19 dB at 10,000 Hz. Thus the Wide-Range system was flat to 6000 Hz, and it produced usable response at 8000 Hz. This frequency range is approximately that used for speech tracks in motion pictures, which are filtered at 8000 Hz. It is considerably wider than amplitude-modulation radios, which are usually limited to 5000 Hz.

Because subjects heard unfiltered and filtered selections alternately, it was important to choose a filter which could restrict the frequency range without introducing distortion, phase shift, and other contaminants which might draw a subject's attention to its action. After listening to several filters with various high-frequency cut-offs, we chose a Gramer Transformer Corporation No. 423W17 filter. This unit has a nominal passband of 300-3500 Hz ± 1.5 dB, with rejection of 50 dB or more at 5000 Hz and above. Since loading affects a filter's frequency response, the Human Engineering Laboratories' Acoustical Research Branch calibrated the filter with the input and output loads that were used. Its frequency response was then flat within ± 2 dB between 400 and 3600 Hz, attenuating 4000 Hz by 20 dB, and 5000 Hz by more than 50 dB. Low-frequency response began decreasing at 800 Hz, reaching a 10-dB drop at 90 Hz.

For practical purposes, then, the Filtered condition removed all frequencies above about 3600 Hz, while the Wide-Range system reproduced somewhat more than another octave of high frequencies. The filter's high-frequency limit, which is roughly the same as with an ordinary telephone, may appear drastic. However, actual pilot tests with listeners who were not familiar with the selections showed that they did not detect any difference between adjacent selections.

The filter was connected to a toggle switch, so it could be switched into and out of the circuit noiselessly.

The master tape which Muzak had prepared was played through (or past) the filter, electronically compressed into a dynamic range of 20 dB to restrict variations in physical intensity, and recorded on a 1163-foot Fidelipac tape cartridge at 3 3/4 inches per second. The filter was switched into the circuit before each starred selection, then switched off again at the end of the starred selection.

During the experiment, the subjects heard the music program over their loudspeakers. The loudness of the music at the subjects' ear positions ranged between 55 and 65 dB re 0.0002 microbar, as measured with a Bruel and Kjaer type 2203 Precision Sound-Level Meter.

Vigilance Task

This experiment used the same modified vigilance boxes as the preceding study (4). Briefly, each subject saw four 6E5 "magic-eye" tubes, mounted 1 1/2 inches apart (Fig. 1). The control grids of these tubes were normally grounded, giving a wide shadow at the bottom of the tube (from left to right, Tubes 1, 2, and 4). To display a stimulus, the tube's grid was biased with a 1-1/2-volt battery, narrowing its shadow to about half its normal width (see Tube 3 in Fig. 1).

Immediately below each stimulus tube, there was a pushbutton. The subjects were instructed to press these buttons to show they had perceived a stimulus.

The intervals between stimuli depended on several restrictions. It was stipulated that 16 stimuli would be given during the one-hour session, spaced no closer together than 1 1/2 minutes, and no farther apart than 5 1/2 minutes. The experimental conditions for stimuli (Wide-Range vs. Filtered music) were counterbalanced within each quarter hour of the session. During each quarter hour, the first and fourth stimuli appeared during Wide-Range selections, and the middle two during Filtered selections. The exact stimulus times were varied unsystematically so subjects could not learn to anticipate them.

The sequence of the four display tubes was determined from a table of random numbers, with the stipulations that a given stimulus must not occur more than twice in a row, and that each stimulus must occur about equally often. As a matter of fact, the random sequence exactly fulfilled both of these conditions.

The stimulus times and sequences are listed, in relation to the music program, in the third and fourth columns of Table 2.

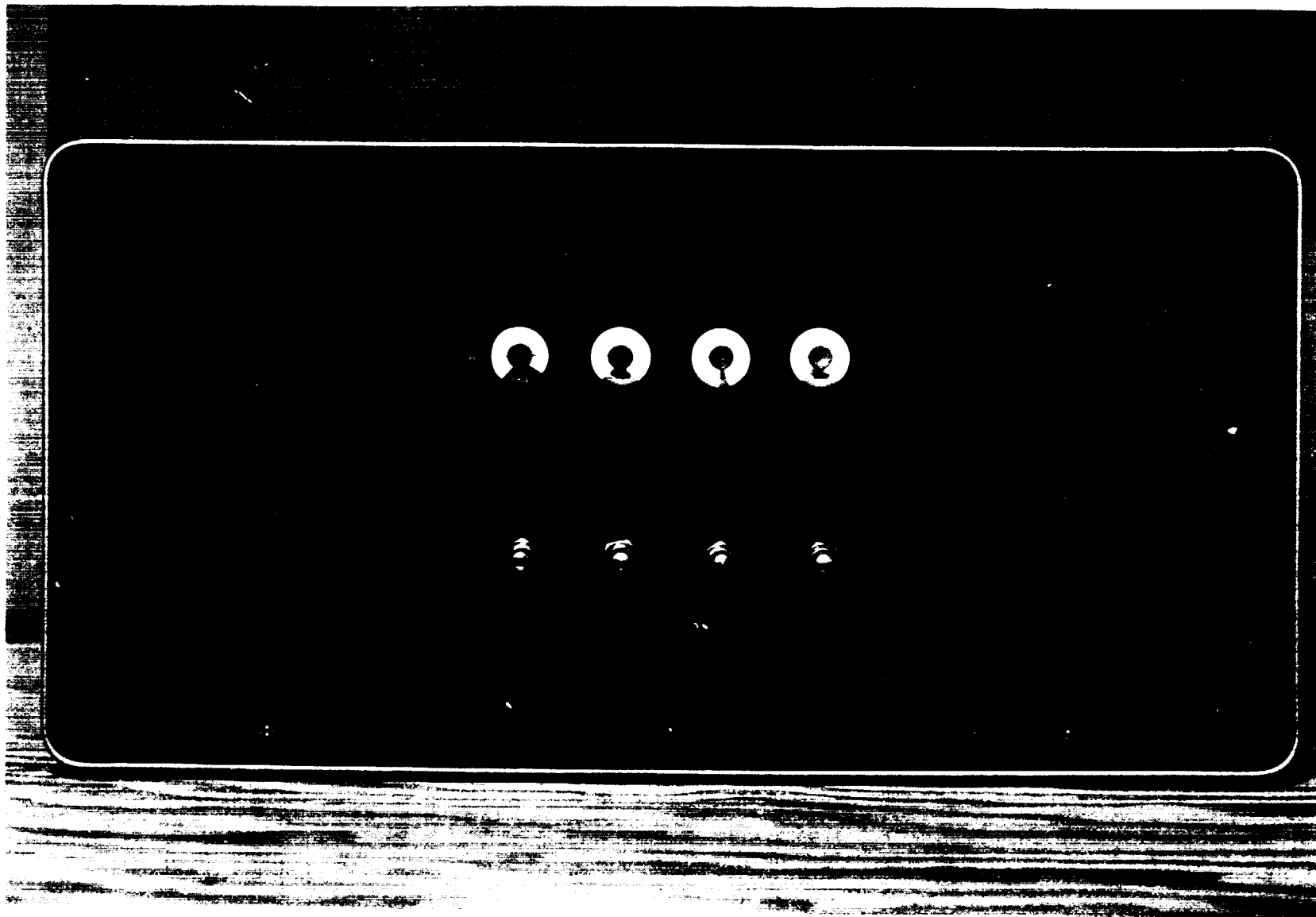


Fig. 1. VIGILANCE BOX
(Third tube from left displays a stimulus.)

Control and Data-Recording Equipment

The music program was recorded on one track of a magnetic-tape cartridge. Two tones, recorded on another track of the same cartridge, controlled stimulus selection and presentation automatically. This arrangement guaranteed that the stimuli were always given in the same order and at exactly the same points in the music program.

The subjects' response times were recorded on four tracks of a magnetic tape, one track corresponding to each of the four booths. A timing tone of known frequency was gated onto the tape when stimuli were presented, and turned off when a subject pressed the correct pushbutton. Later, these tone bursts were played back into an electronic counter. The cycle counts, when divided by the timing-tone frequency, gave response times correct to the nearest millisecond.

This apparatus has already been described in detail elsewhere (4).

Procedure

The subjects were tested in groups of three or four, each in a separate booth. All of the experimental sessions were scheduled to begin at three o'clock, to minimize any effects that differing times of day might have on a subject's alertness.

To assure that every subject received exactly the same instructions, they were recorded on a separate tape cartridge, complete with control tones that selected and presented two stimuli to illustrate the directions. After each subject was seated in his booth at the beginning of the experimental session, he heard these instructions over his loudspeaker:

Modern missile systems are becoming more and more automated. Once a target has been detected, the system practically runs by itself -- it can track the target automatically, compute its course, and fire at it until it has been destroyed. But soldiers still have to keep watch on radar scopes to detect targets in the first place, and to decide which targets to fire at. This experiment will measure how well you can detect target signals.

The box in front of you has four electronic tubes in it, representing the four sectors a target can approach from. Notice that each tube has a wide shadow at the bottom -- this means there aren't any targets in that sector.

Now if a target does appear, one of the shadows will narrow to about half the size it is now. Watch. (Stimulus appears.) When a shadow does narrow, you should push the button under that tube. Push it now. (Pause)

This is how you tell the computer to track in that sector. Notice that, when you push the button, the shadow widens back to its normal size as the computer takes over.

When you see a target, push the button firmly until you hear it click, and then hold it down for a moment until you see the shadow go back to normal. Let's try it again for practice, to see how fast you can react. (Second stimulus appears.)

The important thing is pushing the button fast. Try to push the button just as quickly as you can when you see a target, because you're being scored on how fast you respond. But be careful not to press the buttons unless you do see a target. If you press a button when there isn't any target, that counts against you as an error.

Notice, too, that your booth is soundproofed, so you won't be distracted by hearing people talking, telephones ringing, and things like that. We have to use soundproofing to keep these noises under control. Our first subjects complained the booths bothered them because they were unnaturally quiet, so now we counteract that by playing background music.

Remember, when you see a target, press the button just as quickly as you can. If you have any questions, open your door and ask them now. If not, begin watching for targets as soon as the music starts playing.

A short time was allowed to give the subjects an opportunity to ask questions if they wanted to, but no subject requested further instructions. The music program itself began within a minute after the instructions were completed.

Although the subjects were told they would be penalized for responding when there was no stimulus, such responses were not recorded. This instruction was given mainly to discourage subjects from holding buttons down continuously. Observation through the booths' one-way windows showed that subjects virtually never pressed buttons unless there was a stimulus.

At the end of the session, the experimenter asked the subjects rather vague questions, such as, "What do you think the experiment was about?" Although most subjects were willing to hazard a guess, none of them was ever able to verbalize the hypothesis under test. The subjects' comments indicated they were totally unaware that the music's frequency response had changed.

RESULTS AND DISCUSSION

Response Measures and Criteria

In comparing the ways that Wide-Range and Filtered music affected the subjects' alertness, we will use the same three criteria developed in the preceding study: mean response times, variabilities, and intrasubject reliabilities.

If Wide-Range music is truly more stimulating, its effect should be reflected in faster response times.

Although there were differences among means in the previous study, the programs had a much more pronounced effect on variability. Hence if the music's frequency response is an important variable, the Wide-Range music should also narrow the variability of response times.

Finally, the subjects' reliabilities -- the extent to which they retain their places in the rank order of response times throughout the hour -- proved to be a sensitive index of differential effects. First, if either condition affects the subjects consistently throughout the hour, the quarter-hour means for that condition should show correlation with each other. Second, if Wide-Range music and Filtered music affect subjects differently, there should be little correlation between performance under the two conditions.

Thus a music program would have greatest practical efficacy if it produced these three effects:

1. Shorter mean response times.
2. Less variable response times (smaller variances).
3. Higher individual reliabilities (larger correlations between a subject's performance during different time periods).

Mean Response Times

As in the previous studies, the number of stimuli was selected so individual response times could be pooled to get more stable estimates of the parameter, by giving accidental fluctuations an opportunity to offset each other. Statistically, this treatment has the added advantage that it reduces the skewness of individual response-time measurements, yielding a more nearly normal distribution which can be analyzed with parametric methods.

Therefore a total of 16 stimuli was arranged so there were four in each quarter hour: two during Wide-Range selections, and the other two during Filtered selections. While it would have been desirable to give still more stimuli under each condition, it seemed more important to preserve the task's realistic monotony by spacing the stimuli at about the same intervals as in the previous studies. Consequently, a subject's quarter-hour means for each condition are somewhat less stable than before, because they are based on two measures, rather than four.

Within each quarter hour, the conditions were counterbalanced to assure that progressive response changes, such as fatigue and boredom, would have the same net effect on the Wide-Range condition as on the Filtered condition. Thus the means for the two conditions were comparable during each quarter hour.

Table 3 gives the quarter-hour means for Wide-Range and Filtered conditions. Consistently, in each quarter hour, the mean response time was faster with Wide-Range music than with Filtered music. The probability that this would occur by chance is the same as the probability of flipping four unbiased coins and getting four heads -- i. e., one chance in 2^4 , or one chance in 16. Since this is the smallest probability possible with four such events ($p = .063$), it is interpreted as indicating that the subjects responded significantly faster with Wide-Range music than with Filtered music.

Furthermore, even the slowest quarter-hour mean for Wide-Range music (.936 second) was faster than the fastest one for Filtered music (.962 second). All four means for the Wide-Range condition were faster than any of those in the Filtered condition. This finding verifies the prediction based on O'Neill's theory; the music did maintain alertness better when it had a wide frequency range and, as a result, more variation in instrumentation.

Comparing the two means for individual quarter hours, the Wide-Range and Filtered conditions differed very significantly during the second quarter hour ($t = 2.44$, $p = .0073$). The difference between conditions also verged on significance during the first quarter hour ($t = 1.44$, $p = .076$). Although the third and fourth quarter hours did differ in the predicted direction, these means, taken individually, did not differ enough to reach statistical significance.

TABLE 3

Mean Response Times (Seconds) and Variances
for Wide-Range and Filtered Selections, by Quarter Hours

Condition	Quarter Hour	Mean	Variance
Wide-Range	1	.887	.052
	2	.909	.092
	3	.921	.112
	4	.936	.195
Filtered	1	.986	.150
	2	1.106	.208
	3	.962	.255
	4	.966	.379

It seems noteworthy that even the slowest quarter-hour mean in this experiment (1.106 second) was faster than the fastest one in the previous study (1.121 second). Since the conditions of the two experiments differed in several ways, this improvement cannot be attributed conclusively to any one variable. It seems likewise inappropriate to compare the results statistically. Nevertheless, the two situations were generally comparable, and both used enough subjects to assure reasonably stable estimates of the population means. The most important difference between the two experiments is that the new program, used here, included far more selections rated "bright" and "fast," and only one judged "slow." Thus it seems eminently reasonable to attribute the improvement in performance here to the more-stimulating musical program.

The trend of quarter-hour means within the Filtered condition was not an orderly one: these response times were somewhat longer during the first half hour, and particularly long during the second quarter hour. These degraded response times represent the well-known vigilance decrement, which typically appears after about half an hour at the monotonous task. Note, however, that the longest response times occurred during the second quarter hour. In the previous study, using a less-stimulating musical program, response times were longest during the third quarter hour. Apparently the new musical program, with greater stimulation, partially offset the vigilance decrement. The second-quarter decrement seen here might be reduced even further by increasing the program's stimulation values during the second quarter.

In fact, the unfiltered condition seemed to do exactly that. The means for quarter hours indicate that Wide-Range music afforded greater stimulation than Filtered music. Correspondingly, the trend of the Wide-Range means was a steady progression, with each quarter slightly slower than the one before it; the abrupt vigilance decrement vanished completely.

Altogether, these results virtually specify the program of stimulation which will give best performance at tasks like the one used here. In the previous study, the ascending program's stimulation values increased very gradually during most of the hour, finally rising sharply in the last few minutes. The present study, using greater average stimulation values and a more-nearly linear increase, reduced response times considerably and smoothed out the third-quarter vigilance decrement. However, the means still showed small, though steady, increases during the hour. As a hypothesis for further experiments, it might prove effective to increase stimulation even more sharply during the first half hour, and then more gradually thereafter.

In summary, the quarter-hour means unmistakably demonstrate that Wide-Range music is more stimulating than Filtered music, affirming that instrumentation does affect alertness at the vigilance task. Furthermore, the means from this study and the preceding one strongly suggest that making the program more stimulating has directly improved the subjects' response times.

Variability of Response Times

An unexpected finding in the previous study was the dramatic effect the musical program exerted on the subjects' variability. This area deserves careful scrutiny, since minimizing variabilities offers a most attractive opportunity to improve the predictability of behavior.

Variances for each of the conditions, by quarter hours, have already been presented in the fourth column of Table 3. Both conditions showed the same regular trend: the subjects became progressively more variable during the hour. The F ratios in Table 4 evaluate the significance of this increasing variability for each experimental condition. These F 's reveal that, of the three pairs of adjacent quarters, two show significant increases in variability with the Wide-Range condition -- perhaps because its initial variability was so small -- although none of the pairs of adjacent quarters differed significantly with the Filtered condition. The remaining three comparisons involve quarter hours which are temporally separated from each other; all three pairs differed significantly, for both conditions. Clearly, the subjects did become more variable as the hour wore on.

TABLE 4

F Ratios Comparing Variabilities Between Quarters of Program

Quarter Hours Compared	Condition	
	Wide-Range	Filtered
1 vs. 2	1.771*	1.387
2 vs. 3	1.217	1.226
3 vs. 4	1.741*	1.486
1 vs. 3	2.154**	1.700*
2 vs. 4	2.120**	1.822*
1 vs. 4	3.750**	2.527**

** Significant beyond .01 point.

* Significant beyond .05 point.

The Wide-Range condition gave considerably smaller variances than the Filtered condition did. As a matter of fact, only the last quarter of the Wide-Range condition was as variable as the very first quarter of the Filtered condition. The F ratios in Table 5 test the statistical significance of these differences. Subjects were very significantly more variable in the Filtered condition during the first three quarters, and significantly so during the last quarter. Thus the subjects were always significantly less variable with Wide-Range music than they were with Filtered music.

We may also compare these variances with those engendered by the less-stimulating ascending program in the previous study. With the previous program, the overall variance was .384 -- almost exactly twice the variance of the most-variable quarter in this study. Even during its least-variable quarter, the previous program produced a variance of .156, which is greater than three of the Wide-Range quarters here.

There can be little question that the musical program's stimulation value has again exerted a profound influence on the subjects' variabilities. Making the program more stimulating, by substituting selections which are rated more stimulating, reduces the variability of response times. Alternatively, making the program more stimulating by giving Wide-Range music, rather than Filtered music, also makes response times less variable. In essence, more-stimulating programs give better control over variability.

TABLE 5

F Ratios Comparing Variabilities
Between Conditions, by Quarters

Quarter Hour	<u>F</u> Ratio
1	2.885**
2	2.261**
3	2.277**
4	1.944*

** Significant beyond .01 point.

* Significant beyond .05 point.

Consistency (Reliability) of Individual Performance

The third criterion is individual consistency during the hour -- the extent to which individuals maintain their relative positions within the group. The previous study noted that some conditions can disrupt individual consistency. Such effects are very undesirable, since they make it impractical to select personnel for vigilance tasks, or even to predict how adequate their performance will be.

As before, individual consistency has been evaluated with Spearman rho correlation coefficients, comparing the subjects' performance during quarter hours of the same experimental condition (Table 6). With the Wide-Range music, five of the six rhos reached significance, and two of them were very significant (p less than .01). These results indicate that the subjects did respond consistently while listening to Wide-Range music.

TABLE 6
Correlations Between Response Times for Quarter Hours
Within the Same Condition

Quarter Hours Compared	Condition	
	Wide-Range	Filtered
1 vs. 2	+.307*	+.088
2 vs. 3	+.356**	+.109
3 vs. 4	+.269*	+.275*
1 vs. 3	+.247	+.178
2 vs. 4	+.414**	+.006
1 vs. 4	+.310*	+.215

** Significant beyond .01 point.

* Significant beyond .05 point.

Parenthetically, we should note that the correlations between quarters are smaller here than in the previous study. The alternation between Wide-Range and Filtered conditions, analogous to the Increasingly Variable program used before, may well have reduced these correlations below those characteristic of an uncomplicated ascending program.

With Filtered music, only one of the six rhos was statistically significant. Apparently the effect of Filtered music varies considerably during the hour, so that it becomes difficult to predict whether a person will do poorly or well.

Since it is known that subjects stay more alert in some quarters than in others, we might reasonably expect their alertness to depend mostly on time of the hour, regardless of whether they are listening to Wide-Range or Filtered music. The rhos in Table 7 correlate the two conditions for each quarter. The coefficient for the third quarter hour is very significant, but the other three do not differ significantly from zero. This finding contradicts our expectation: variations in alertness depended mostly on the music's frequency range, rather than on time of the hour.

TABLE 7
Correlations Between Response Times
Under Wide-Range and Filtered Conditions, by Quarters

Quarter Hour	Correlation Coefficient
1	+.183
2	+.164
3	+.416**
4	+.202

** Significant beyond .01 point.

Thus the individual-consistency criterion leads to the same conclusion as the other two indices: the music's frequency range does affect performance at the vigilance task, and Wide-Range music gives better alertness than Filtered music.

Conclusions

The three criteria agree in demonstrating that Wide-Range music maintains the promptness of response times significantly better than Filtered music. This finding means that the music's instrumentation, which was controlled through filtering, does affect performance. Thus it validates another aspect of O'Neill's theoretical position and broadens the scientific basis for manipulating instrumentation as one means of maintaining the human operator's alertness. In addition, the results imply that realizing music's full potential for improving performance will require good audio equipment which can reproduce an extended frequency range. Speech-range audio systems -- such as intercoms, with their restricted frequency ranges -- will be significantly less effective.

SUMMARY

1. This experiment aimed to determine whether the instrumentation of a musical program affects response times on a vigilance task. Instrumentation was varied by restricting the music's frequency range, thus eliminating many of the overtones that determine a sound's timbre.

2. Forty-one subjects worked at the task for one hour while listening to a program of 23 musical selections. The first selection (and other odd-numbered selections) were played with a wide frequency range. Even-numbered selections were filtered to remove frequencies above 4000 Hertz (Hz), and to gradually attenuate low-frequency response below about 800 Hz.

3. Response times were averaged for each of the two conditions, by quarter hours. The subjects responded consistently -- and significantly -- faster with Wide-Range music than with Filtered music. All four Wide-Range means were faster than the shortest Filtered mean.

4. As in the previous study, the musical program affected variabilities even more extensively than means. For every quarter hour, the subjects were significantly less variable when listening to Wide-Range music. For three of the four quarters, variability with Wide-Range music was lower than it ever was with Filtered music.

5. While listening to Wide-Range music, the subjects showed significantly greater consistency, as measured by rhos correlating mean performance during quarter hours. Five of the six pairs of quarters were correlated significantly or very significantly during Wide-Range music, but only one pair showed a significant correlation during Filtered music.

6. The Wide-Range and Filtered conditions appeared to have different effects on the subjects, since three of the four quarters showed no significant correlation between the two conditions. Thus response times depended more heavily on the experimental conditions than on time of the hour.

7. All of these results demonstrate that the music's instrumentation does affect alertness significantly, and that an extended-range audio system is required to take full advantage of instrumentation as a tool for maintaining peak alertness.

8. The new program of music used here was designed to give considerably greater stimulation than the one used previously. Its greater stimulation values probably account for generally faster responses and lower variability than in the previous study.

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<p>This experiment tested whether music's instrumentation affects response times on a vigilance task. Instrumentation was varied by restricting the frequency range, thus eliminating many of the overtones that determine timbre. Forty-one subjects worked at the task for one hour while listening to a program of 23 selections, alternately Wide-Range and Filtered. The subjects showed significantly better alertness during the Wide-Range condition throughout the hour. The Filtered condition gave slower responses, greater variability, and inferior individual consistency. Hence the music's instrumentation had several significant effects on alertness. In addition, the more-stimulating musical program here appeared responsible for faster responses and lower variability than in the preceding experiment.</p>			

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